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ABSTRACT

Concept maps provided a measure of subjects' cognitive structures before and after completion of an environmental education course. Concept maps were constructed from expressions taken from the issue "global climate." Expressions were assigned to one of three domains: science, technology or society. Maps were analyzed by constituent propositions, which were categorized by various characteristics including the domains of the expressions connected, the relationship expressed and the strength, determined by a protocol developed for this study. Significant differences were found in the frequencies of occurrence for various proposition characteristics and these were correlated with previous academic experiences. Some proposition characteristics were also correlated with the results of a final examination. Comparison of concept maps prepared before and after an environmental education course showed some changes in proposition characteristics. A brief description of the course, the expressions used in the concept mapping activity, a description of "networking" symbols and a sample map, the protocol used to evaluate the concept maps, and the results of the statistical analysis are appended. (Author/KR)

Effects of an Environmental Education-Related STS Approach Instruction on Cognitive Structures of Preservice Science Teachers'

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Abstract

Concept maps provided a measure of subjects' cognitive structures before and after completion of an environmental education course. Concept maps were constructed from expressions taken from the issue "global climate." Expressions were assigned to one of three domains: science, technology or society. Maps were analyzed by constituent propositions, which were categorized by various characteristics including the domains of the expressions connected, the relationship expressed and the strength, determined by a protocol developed for this study.

Significant differences were found in the frequencies of occurrence for various proposition characteristics and these were correlated with previous academic experiences. Some proposition characteristics were also correlated with the results of a final examinations. Comparison of concept maps prepared before and after an environmental education course showed some changes in proposition characteristics.

Introduction. Martin (1985) identified four categories under which various goals of science education might fall. These categories are goals relating to: 1) the the acquisition of knowledge, 2) the acquisitions of skills, 3) the building of understanding and 4) the development of propensities to behave in certain ways. STS curricula offer a unique opportunity for development in all four categories. STS education can be a vehicle for widening the areas in which students perceive science information to be relevant. Associations between science concepts and other aspects of the students lives may result in reinforcement of the science concepts and allow more opportunities for transfer of these concepts to problems outside the classroom. A hieghtening of perceived relevance of science concepts may generate more interest in science courses and careers and a more positive and realistic attitudes towards science. In spite of the potential cognitive benefits, the preponderance of investigation of STS curricula has focused on Martin's fourth goal only (Waks and Prakash, 1985, Yager et al., 1988 and Rubba and Wiesenmayer, 1985). Mitchener and Anderson (1989) cited content and evaluation as concerns which caused science teachers to question the acceptance of STS curriculum. If STS is to be accepted, work must be done to develop techniques for evaluating and exploiting the potential of STS curricula. This study was a is a beginning. .

The focus of this study was on the potential to affect two of Martin's four goals: goal 1, acquisition of knowledge and goal 3, building understanding. Concept mapping provided the primary source of data for this study, and a method of evaluating concept maps is introduced. The study examined the effects of the "four goal" STS approach (Rubba and Wiesenmayer, 1985 and Bell and Wiesenmayer, 1990) on students cognitive structures related to the environmental education issue, "global climate," the relationships of those structures to course credit hours accumulated in science, mathematics and social science courses and the relationship of those structures to subject performance on a final examination.

Research Questions. The main question of this study was, "how does STS instruction affect cognitive structure?" The primary method of measuring cognitive structures was concept mapping. The utilization of concept maps as a measure allowed the respondent some of the flexibility of an essay examination; however, with concept maps there is the possibility of a quantitative analysis, more easily obtained than is possible with an essay response (Surber, 1984). The use of concept maps resulted in a new question, "what is the relation between cognitive structure and concept maps?" To answer this question it was necessary to look at patterns within the concept maps, and to relate these patterns to other more traditional measures, i.e. college course credits and examination scores.

Subjects. 16 college students enrolled in an environmental education course were the subjects of this study; 8 female and 8 male. The subjects were working towards secondary certification in one of three science areas: biology (12 subjects), earth and space science (3 subjects) and physics (1 subject).

Procedure. The cognitive structures of the subjects were measured at the beginning of an environmental education course in which they were enrolled. Cognitive structures were measured by analysis of concept maps produced in a concept mapping activity. The subjects then participated in discussions, projects and other class activities as part of the course. A brief description of the course is found in Appendix A. On the last scheduled meeting of the class the subjects completed a questionnaire soliciting information about their previous academic experience, and produced a second concept map. The instructions for the concept mapping activities were identical for both occasions; however, the first maps were constructed as an out-of-class activity while the second maps were constructed during class period. This difference did not seem to have an effect, as, on the second mapping activity, all subjects completed their maps prior to the end of the class period. After completion of the course the subjects were evaluated by a final examination.

Instruments. The survey was a simple form which asked the subjects to report the number of credit hours they had completed in one of three broad areas. The three areas were: 1) science, 2) mathematics and 3) social science.

The final examination was constructed by the instructor of the course and covered a wide range of environmental issues and concepts. The test consisted of 80 multiple choice questions.

The concept mapping activity required subjects to construct a concept map using 36 provided expressions and following a mapping procedure called "networking" (Holley and Dansereau, 1984). The expressions were selected from expressions occurring in concept maps constructed, as part of a previous study, on the topic "global climate" (McClure, 1989, McClure 1990). The list of expressions appears in Appendix B. A description of "networking" symbols and a sample map appear in Appendix C. The same list of expressions was used in both mapping activities, and although "global climate" was one of the expressions listed, the subjects were not given this as a topic for their maps.

Analysis of the maps was accomplished by recording the frequencies and characteristics of the propositions composing individual concept maps. A proposition consisted of two expressions connected by an arrow, labeled to indicate the nature of the relationship between the expressions. The expressions used were classified into three domains: science, technology and society. Propositions were place into 1 of 6 categories depending on the domains of the expressions connected. The 6 categories are summarized in Table 1 below.

Table 1.
Proposition Categories and Descriptions

Category	Description
Science	Connecting two expressions from the science domain.
Technology	Connecting two expressions from the technology domain.
Society	Connecting two expressions from the society domain.
Science/Technology	Connecting two expressions one from the science domain and one from the technology domain.
Science/Society	Connecting two expressions one from the science domain and one from the society domain.
Technology/Society	Connecting two expressions one from the technology domain and one from the society domain.

A second characteristic of the propositions recorded was the relationship type connecting the expressions. As shown in Appendix C, there are 6 relationships allowed in the networking scheme. The 6 can be grouped into three general types (Holley and Dansereau, 1984). The 3 relationship types and their descriptions are summarized in Table 2.

Table 2.
Relationship Types and Descriptions.

Relationship Type	Symbols	Description
Hierarchy	"p" and "t"	Relationships expressing a superordinate/subordinate relationship between two expressions.
Attributional	"c", "e" and "a"	Relationships describing one expression as an attribute or amplifying descriptor of the other expression.
Causal	"l"	Relationships which indicate that one expression influences or causes another, or occurs in a temporal sequence.

Finally the strength of each proposition was determined by the use of a protocol. The protocol is described in Appendix D and was developed for this study. Other scoring protocols, such as that suggested by Novak and Gowin (1984), look at the overall quality of the concept map. The protocol used in this study focuses on the quantification of individual propositions within the concept maps, allowing the analysis of substructures within the maps. The substructures in this case refers to propositions grouped by common characteristics as described above.

Results. The data for the frequencies and average scores for the propositions of the concept map are presented in the tables of Appendix E. Analysis of the concept maps revealed several consistent patterns. As can be seen from these tables the science and society categories were the two which were most frequently constructed. These two types of propositions occurred with approximately equal frequency, and occurred nearly twice as often as any other type of proposition. Among proposition types connecting concepts from different concept domains, propositions connecting science concepts to technology concepts and technology concepts to society concepts occurred four times as frequently as propositions connecting science to society concepts. ANOVA tables and pair-wise comparisons between proposition categories are found in Appendix F.

There were also significant differences in the frequency with which subjects identified certain relationship types. Hierarchy types were identified most frequently, followed by causal types and attribution types were identified least frequently. The difference between hierarchy and attribution was significant for the first group of concept maps, while for the second group of concept maps the heirarchy relationship type was segnificantly higher then both other relatinship types. Appendix G provides the details of this analysis.

Significant interactions were found between relationship type and proposition category. Hierarchy type relationships were dominant in the science and technology proposition types, while the frequency of relationships was more evenly distributed for the society propositions. Appendix H illustrates these interactions.

Because of the low numbers of propositions identified for some of the cross domain proposition categories, these three categories were combined for the analysis of the average scores. Average scores for each proposition type were calculated for each individual concept map and the means of these averages were used in the analysis. For the maps constructed in the first mapping activity, there were no significant differences in the average scores of the different proposition categories. The ANOVA of the second group of concept maps, however did show some significant differences among the proposition categories. Pair-wise comparison, by Fisher LSD, found differences between the technology and society categories and the cross domain proposition category. Appendix I contains the ANOVA tables and the comparisons.

For relationship type, the highest average scores were found in propositions expressing causal relationships. Causal relationships from the first and second group were found to have average scores significantly higher than for either hierarchy or attribution type relationships. Appendix J contains the ANOVA table for this data.

Significant interactions occurred for average scores between the proposition categories and the relationship types for concept maps from both groups. The variation between relationships with proposition seemed to occur mostly in the causal and attribution relationship types, while propositions formed with hierarchy relationships seem to have roughly the same average score. Appendix K shows the analysis of the interactions.

Correlations of concept map attributes to reported course credits resulted in several interesting results. A statistically significant correlation ($r = .643$) was found between the total number of propositions of an individual's concept map and the number of science credits reported by that individual. The correlation between science credits reported and the number of propositions connecting concepts from the technology domain was also significant ($r = .628$), as was the correlations between reported science credits and the average score of propositions connecting concepts within the technology domain ($r = .518$).

This same proposition type was correlated with the final examination score. A significant correlation was found between average score of propositions connecting concepts within the technology domain and the final examinations score ($r = .503$). A table summarizing the correlation results is found in Appendix L.

ANOVA with proposition categories and relationship types indicated that no significant change occurred within the attributes either by frequency or by average score from the first to the second mapping; however, a simple t-test of the total numbers of propositions constructed on the first and second mapping activities did show that there was overall a significant increase. A similar analysis of the total average score of concept maps found no significant change from the first to the second mapping.

Discussion. The main purpose of this experiment was to evaluate changes in the cognitive structure of subjects. Changes did occur although the design of the study does not allow that these changes be definitely attributed to participation in the course. Increases were found in the number of propositions identified from the first to the second mapping activities.

The increase in the total number of propositions seemed to be limited to those propositions which connected concepts within the same domain, i.e. science-to-science and society-to-society. It was expected that the STS orientation of the course would result in an increase in the propositions connecting concepts from different domains; this did not occur. It appears tnat the learning was limited to the addition of information to existing structures, and that no restructuring of information occurred. If this is the case, then it may be expected that the richest domains would show the greatest increase, richer domains offering more ways to incorporate new information. The majority of the increase in propositions did occur within those proposition types which connected concepts within the science and society domains, and were the most frequently occurring types in the first mapping activity reflecting the richness of the subjects' cognitive structures within these domains.

Correlations between concept map attributes and other measures lead to some interesting speculations. The correlations between reported science credits and the attributes of propositions connecting concepts within the technology domain may indicate that science was the source of the majority of these students' technological information. The correlation of the average score of propositions in this domain with the examination scores is also a reflection of the course content.

The failure of science credits to correlate with the number of propositions connecting concepts from the science domain may be attributed to the nature of the science courses completed by the subjects. The majority of subjects, 12 of 16, were in a biology education program and it may be assumed that the science credits reported were generally from this area. The expressions from the science domain, used in this study, would more likely be found in earth science courses. Future studies must take a more detailed look at the nature of credits reported by the students. Science as a type of previous academic experience is too broad.

Some comments regarding the use of concept maps as a method of evaluating cognitive structure can also be made. The mapping activity did seem to be somewhat sensitive to change in individuals cognitive structure. That the concept map analysis was sensitive to individual differences is supported by the correlations found between the concept map attributes and previous academic experience and scores on the final examination.

There were several possible sources of noise in this study, which may have reduced the sensitivity of the map analysis. The subjects' unfamiliarity with the concept mapping technique may have obscured the relationship between the cognitive structure of the individual and the concept maps. Also, the content of the course was very broad, and the change in subjects' concepts of global climate may have been very small. Future studies must provide for thorough instruction in the concept mapping technique to be used, and focus of the instruction and the mapping activities more closely matched.

The use of concept maps points out the complexity in the differences of cognitive structures and the problems associated with assessing learning with any instrumentation. In the analysis of the maps it was apparent that the subjects had assumed meanings for the expressions which had not been considered by the researchers. There is also some question of to what extent the cognitive structures indicated by the concept maps were constrained by the researchers choice of expressions, and what effect this constraint had on the interaction of proposition attributes and changes from the first to the second mappings.

The maps did provide a rich source of data, quantifiable in a variety of ways. Future studies will attempt to refine the use of maps, and to eliminate some of the noise of the system.

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APPENDIX A

Nature and Scope of an STS-Based Environmental Education Course

STS includes concerns that are derived from other educational movements, including the environmental education tradition. Some of those movements were also antecedents to or spin-offs from environmental education. Any environmental education methods course should review those traditions, preferably with meaningful activities. Students in the course will perform the following activities, representing other educational thrusts:

Traditions	Activities
Natural History	Each student conducted a natural history study on a subject of his/her choice.
Conservation	Each student performed two studies in which he/she conserves over the course of the semester: (1) some form of energy (2) use of some product.
Ecological	Flora, Fauna, Geology of Mt. Nittany.
Environmental	(1) Water quality of a duck pond. (2) Ground water preservation measures in new commercial developments (3) Groups study the effects of different factors on the biodegradability of newspaper.
Technological	(1) Each student traced the development of a technology of his/her choice. (2) Groups determined the technologies necessary for removing water pollutants of various kinds.
Society	Groups analyzed the relative national values underlying the funding of various kinds of research (Federal budget for 1987)
STS Issues	(1) Each student collected weekly news clippings on environmental issues. (2) Groups developed an STS teaching unit on some facet of global climate (3) Groups competed in a trade-off exercise which balanced nutrition against food cost, packaging, preparation energy and shopping time and energy.

In addition, students used as textbooks, *Environmental Science, Third Edition*, (S.H. Anderson, R.E. Beiswenger, and P.W. Purdom), and *State of the World, 1989* (L. Brown, et al., 1989)

The course emphasis was not tightly conducted as a management by objectives approach. Field and hands-on experiences were emphasized as the referent for classroom discussions based on readings and selected topics from the video series,You, Me, and Technology (M. Galey, 1987). Only three information lectures were given: one on the history of environmental education, a second on the history of environmentally related human values based on the book, Technology, Environment, and Human Values (I.G. Barbour, 1980), and chemical reactions in the atmosphere.

APPENDIX B

Science Expressions	Technology Expressions	Society Expressions
Atmosphere	Industry	Consumers
Radiation	Power Generation	Population
Volcanoes	Agriculture	Needs
Acid Rain	Telecommunication	Desires
Global Climate	Biotechnology	Government
Oceans	Atomic	Politics
Decomposition	Fossil Fuel	Jobs
Ultra Violet	Computers	Information
Infra Red	House	Attitude
Heat	Engineering	Awareness
Carbon		Solution
Pollution		Decisions
Chemicals		
Gases		

Appendix C

Key: (the arrow indicates the direction of the relationship)

c - Characteristic of: $A \xrightarrow{c} B$ B is a Characteristic of A

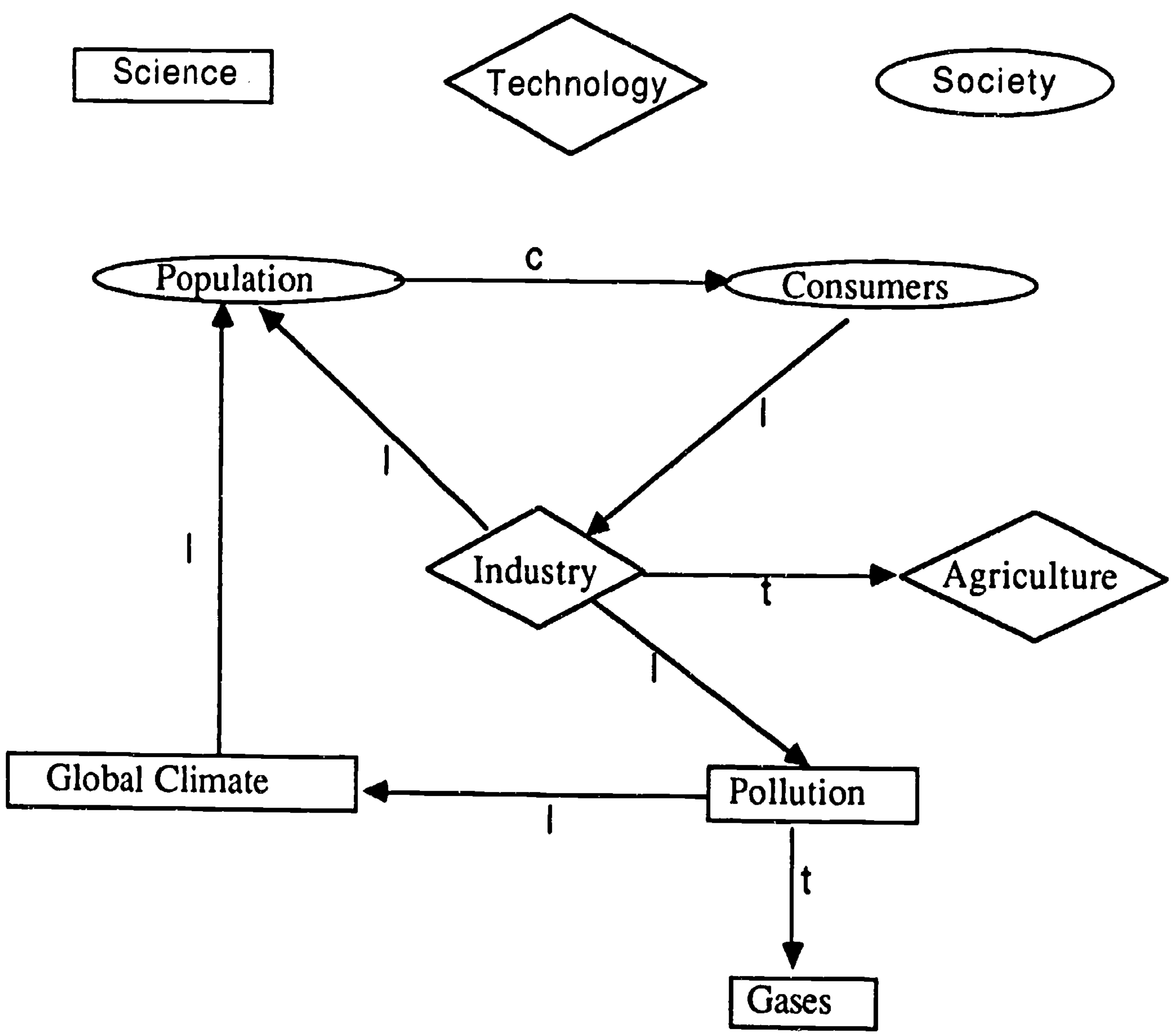
p - Part of: $A \xrightarrow{p} B$ B is a part of A

t - Type of $A \xrightarrow{t} B$ B is a type of A

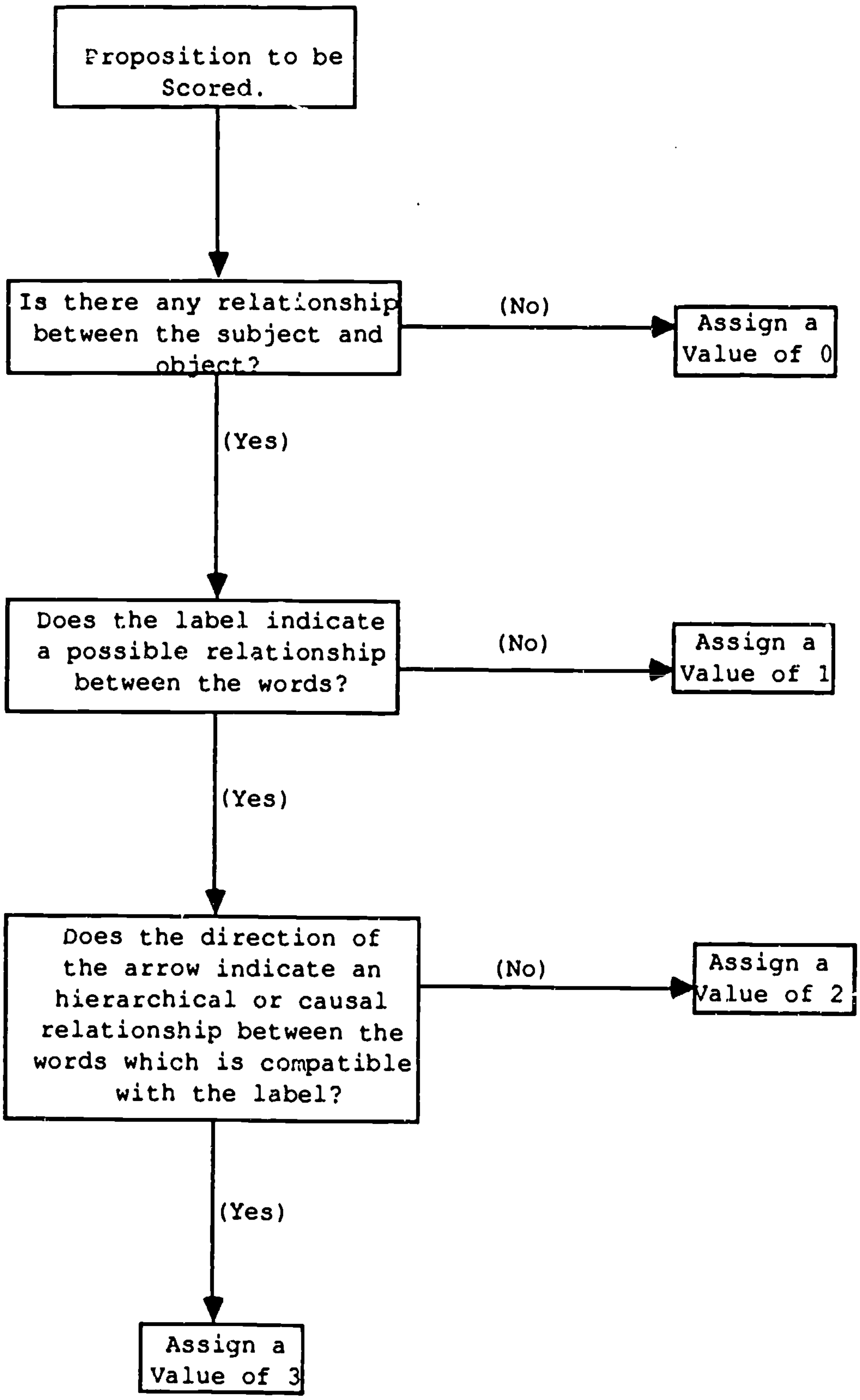
e - Evidence for $A \xrightarrow{e} B$ A provides evidence for B

a - Analogous to $A \xrightarrow{a} B$ A is similar to B

l - Leads to (causes) $A \xrightarrow{l} B$ A leads to, or Causes B



APPENDIX D


Proposition to be Scored.
Is there any relationship between the subject and object?
(No)
Assign a Value of 0
(Yes)
Does the label indicate a possible relationship between the words?
(No)
Assign a Value of 1
(Yes)
Does the direction of the arrow indicate an hierarchical or causal relationship between the words which is compatible with the label?
(No)
Assign a Value of 2
(Yes)
Assign a Value of 3

Appendix E

Table 3.
Frequency of Propositions Categor}

Observation	Statistic	Total	Sci..	Tech.	Soc.	Sci/ Tech.	Sci./ Soc.	Tech/ Soc.
1st Mapping Activity	Freq.	565	166	74	140	75	19	91
	Mean	35.3	10.4	4.6	8.8	4.7	1.2	5.7
	Std.Dev.	4.3	1.9	2.0	2.1	1.1	1.2	2.1
2nd Mapping Activity	Freq.	597	183	73	156	85	20	80
	Mean	37.3	11.4	4.6	9.8	5.3	1.3	5.0
	Std.Dev.	3.9	2.7	1.3	2.2	1.8	1.1	1.8

(Proposition Category spans Statistic through Tech/Soc.)

Table 4
Scores of Proposition, by Category

Observation	Stat.	Total	Sci.	Tech.	Soc.	Sci/ Tech.	Sci./ Soc.	Tech/ Soc.
1st Mapping Activity	Sum	1124	316	152	315	107	28	206
	Mean	70.3	19.8	9.5	19.7	6.7	1.8	12.9
	Std.Dev.	11.7	6.1	5.3	7.0	3.3	2.4	5.6
2nd Mapping Activity	Sum	1197	352	166	339	139	29	172
	Mean	74.8	22.0	10.4	21.2	8.7	1.8	10.8
	Std.Dev.	12.6	7.6	3.5	7.0	3.8	2.2	4.5

Table 5
Average Scores of Proposition, by Category

Observation	Statistic	Total	Science	Technology	Society	Cross Domain
1st Mapping	Mean	2.044	1.885	1.876	2.233	1.837
	Std.Dev.	.299	.449	.793	.463	.384
2nd Mapping	Mean	2.011	1.908	2.258	2.148	1.867
	Std.Dev.	.309	.450	.401	.476	.472

APPENDIX F

Table 6
One Factor ANOVA-Repeated Measures for Proposition Category, Frequency 1st Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	15	46.24	3.083	.227	.999
Within Subjects	80	1087.5	13.594		
Categories	5	885.927	171.185	55.442	.0001
Residual	75	231.573	3.008		
Total	95	1133.74			

Table 7
Significant (at 95%) comparisons
Categories,Frequency 1st Mapping

Comparison	Mean Diff.	Sheffe F-test
Science -Technology	5.75	17.133
Society-Technology	4.125	8.817
Science - Science/technology	5.688	16.762
Science - Science/society	9.188	43.741
Science - Technology/society	4.688	11.386
Technology - Science/society	3.438	6.123
Society - Science/technology	4.062	8.552
Society - Science/Society	7.562	29.636
Society - Technology/society	3.062	4.86
Science/technology - Science/society	3.5	6.348
Technology/society - Science/society	4.5	10.493

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Table 8
One Factor ANOVA-Repeated Measures for Proposition, Frequency Category 2nd Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	15	38.573	2.572	.148	.999
Within Subjects	80	1393.833	17.423		
Categories	5	1111.094	222.219	58.946	.0001
Residual	75	282.74	3.77		
Total	95	1432.406			

Table 9
Significant (at 95%) comparisons
Categories,Frequency 2nd Mapping

Comparison	Mean Diff.	Sheffe F-test
Science -Technology	6.875	20.06
Society-Technology	5.188	11.421
Science - Science/technology	6.125	15.922
Science - Science/society	10.188	4.048
Science - Technology/society	6.438	17.589
Technology - Science/society	3.312	4.657
Society - Science/technology	4.438	8.357
Society - Science/Society	8.500	30.664
Soceity - Technology/society	4.75	9.576
Science/technology - Science/society	4.062	7.005
Technology/society - Science/society	3.750	5.968

APPENDIX G

Table 10
One Factor ANOVA-Repeated Measures for Relationship Types, Frequency 1st Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	95	362.208	3.813	1.111	.2684
Within Subjects	192	658.667	3.431		
Relationships	2	42.25	21.125	6.511	.002
Residual	190	616.417	3.244		
Total	287	1020.875			

Table 11
Significant (at 95%) Comparisons Relationship Types, Frequency 1st Mapping

Comparison	Mean Diff.	Sheffe F-test
Hierarchy - Attribution	.938	6.502

APPENDIX G (Page 2)

Table 12
One Factor ANOVA-Repeated Measures for Relationship Types, Frequency 2nd Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	95	462.302	4.866	1.209	.1357
Within Subjects	19 2	772.667	4.024		
Relationships	2	73.521	36.76	9.99	.001
Residual	19 0	699.146	3.68		
Total	28 7	1234.969			

Table 13
Significant (at 95%) Comparisons Relationship Types, Frequency 2nd Mapping

Comparison	Mean Diff.	Sheffe F-test
Hierarchy - Attribution	1.229	9.854
Hierachy - Causal	.74	3.568

APPENDIX H

Table 14
Two Factor Analysis of Variance, Repeated Measures, Relationshipo Type X Proposition Category, Frequency 1st Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Relationship (A)	2	42.25	21.125	5.98	.005
Subjects w/ groups	45	158..958	3.532		
Category (repeated) (B)	5	264.125	52.825	27.281	.0001
AB	10	119.875	11.988	6.191	.0001
B X Subjects w/ groups	22 5	435.667	1.936		

Table 15
Incidence Table Relationship Type X Proposition Category, Frequency 1st Mapping

Repeated Measure	Sci	Tech	Soc	Sci/ tech	Sci/ soc	Tech/ soc	Totals
Causal Relations	16 2.375	16 1.000	16 3.188	16 1.938	16 .688	16 2.062	96 1.875
Attribution Relations	16 2.812	16 .312	16 3.312	16 .750	16 .062	16 1.375	96 1.438
Hierarchy Relation	16 4.75	16 3.188	16 2.000	16 1.625	16 .438	16 2.250	96 2.375
Totals	48 3.312	48 1.500	48 2.833	48 1.438	48 .396	48 1.896	288 1.896

APPENDIX H (Page 2)

Table 16
Two Factor Analysis of Variance, Repeated Measures, Relationship Type X Proposition Category, Frequency 2nd Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Relationship (A)	2	73.521	36.76	10.699	.0002
Subjects w/ groups	45	154.615	3.436		
Category (repeated) (B)	5	347.615	69.523	29.173	.0001
AB	10	123.021	12.302	5.162	.0001
B X Subjects w/ groups	22 5	536.198	2.383		

Table 17
Incidence Table Relationship Type X Proposition Category, Frequency 2nd Mapping

Repeated Measure	Sci	Tech	Soc	Sci/ tech	Sci/ soc	Tech/ soc	Totals
Causal Relations	16 3.000	16 1.562	16 2.312	16 2.375	16 .625	16 1.688	96 1.927
Attribution Relations	16 2.250	16 .500	16 3.750	16 1.125	16 .188	16 .812	96 1.438
Hierarchy Relation	16 5.875	16 2.375	16 3.312	16 1.688	16 .375	16 2.375	96 2.667
Totals	48 3.708	48 1.479	48 3.125	48 1.729	48 .396	48 1.625	288 2.010

APPENDIX I

Table 18
One Factor ANOVA-Repeated Measures for Proposition Category, Average Score 2nd Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	23	22.33	.971	2.282	.0042
Within Subjects	72	30.626	.425		
Categories	3	4.137	1.379	3.592	.0179
Residual	69	26.489	.384		
Total	95	52.956			

Table 19
Significant (at 95%) comparisons Categories, 2nd Mapping

Comparison	Mean Diff.	Fisher LSD
Technology - Cross Domains	.357	2.514
Society - Cross Domains	4.438	8.357

Table 20
One Factor ANOVA-Repeated Measures for Relationship Type, Average Score 1st Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	36	22.44	.568	.739	.8397
Within Subjects	74	56.829	.768		
Relationships	2	7.288	3.644	5.296	.0072
Residual	72	49.542	.688		
Total	110	77.27			

Table 21
Significant (at 95%) comparisons Categories, 1st Mapping

Comparison	Mean Diff.	Sheffe F-test
Causal - Attribution	.526	3.714
Causal - Hierarchy	.56	4.214

APPENDIX I (page 2)

Table 22
One Factor ANOVA-Repeated Measures for Relationship Type, Average Score 2nd Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Between Subjects	36	28.869	.802	1.213	.2393
Within Subjects	74	48.921	.661		
Relationships	2	12.7	6.35	12.62	.0001
Residual	72	36.221	.503		
Total	110	77.786			

Table 23
Significant (at 95%) comparisons Categories, 2nd Mapping

Comparison	Mean Diff.	Sheffe F-test
Causal - Attribution	.679	8.487
Causal - Hierarchy	.75	10.354

APPENDIX K

Table 24
Two Factor Analysis of Variance, Repeated Measures, Relationshipo Type X Proposition Category, Average Score 1st Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Relationship (A)	2	11.803	5.902	6.92	.0055
Subjects w/ groups	19	16.205	.853		
Category (repeated) (B)	3	.36	.12	.294	.8297
AB	6	6.771	1.128	2.76	.02
B X Subjects w/ groups	57	23.305	.409		

Table 25
Incidence Table Relationship Type X Proposition Category, Average Score 1st Mapping

Repeated Measure	Sci	Tech	Soc	Cross Domains	Totals
Causal Relations	7 2.19	7 2.643	7 2.204	7 2.15	28 2.447
Attribution Relations	2 .9	2 .5	2 2.334	2 1.0	8 1.183
Hierarchy Relation	13 1.946	13 1.966	13 1.619	13 1.946	52 1.869
Totals	22 1.929	22 2.048	22 2.061	22 1.925	88 1.991

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Table 26
Two Factor Analysis of Variance, Repeated Measures, Relationshipo Type X Proposition Category, Average Score 2nd Mapping

Source	df	Sum of Squares	Mean Squares	F-Test	P value
Relationship (A)	2	8.628	4.314	6.612	.0059
Subjects w/ groups	21	13.702	.652		
Categories (Repeated) (B)	3	4.137	1.379	4.548	.006
AB	6	7.387	1.231	4.06	.0017
B X Subjects w/ groups	63	19.102	.303		

Table 27
Incidence Table Relationship Type X Proposition Category, Average score 2nd Mapping

Repeated Measure	Sci	Tech	Soc	Cross Domains	Totals
Causal Relations	9 2.315	9 2.907	9 2.901	9 1.862	36 2.496
Attribution Relations	2 2	2 1.5	2 3	2 1.167	8 1.917
Hierarchy Relation	13 1.751	13 2.051	13 1.765	13 1.919	52 1.862
Totals	24 1.983	24 2.326	24 2.294	24 1.835	96 2.11

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Table 28
Correlations of Proposition Frequencies with Completed Credits, First Mapping

Content Area	DF	Total	Sci. to Sci	Tech to Tech	Soc. to Soc.	Sci. to Tech.	Sci. to Soc.	Tech to Soc.
Science	13	*.643	.177	*.628	.211	.328	-.090	.232
Math-ematics	14	.034	.015	.169	-.156	.161	-.024	-.019
Social Science	13	.115	.274	-.197	-.055	.133	.335	-.032

$_{.95}r_{13}$ =.512 and $_{.95}r_{14}$ = .497

Table 29
Correlations of Proposition Average Score with Completed Credits, First Mapping

Content Area	DF	Total	Sci. to Sci	Tech to Tech	Soc. to Soc.	Sci. to Tech.	Sci. to Soc.	Tech to Soc.
Science	13	.447	-.410	*.518	.308	.223	.168	.265
Math-ematics	14	.102	.110	.154	.083	.372	.050	.354
Social Science	13	.200	.385	.182	.044	-.148	.127	.198

$_{.95}r_{13}$ = .512 and $_{.95}r_{14}$ = .497

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Table 30
Correlations of Proposition Frequencies and Average Scores of Second Mapping Activity with Score from Final Examination.

Content Area	DF	Total	Sci. to Sci	Tech to Tech	Soc. to Soc.	Sci. to Tech.	Sci. to Soc.	Tech to Soc.
Freq.	14	-.447	-.296	-.192	-.064	-.249	-.211	-.008
Average Score	14	.367	.110	*.503	.170	.298	.179	.083

$_{.95}r_{14} = .497$